A STATISTICAL ANALYSIS OF THE EFFECTIVENESS OF PROGRAM INITIAL CONDITIONS AS PREDICTORS OF WEAPON SYSTEM ACQUISITION PROGRAM SUCCESS

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THESIS

A Statistical Analysis of the Effectiveness of Program Initial Conditions as Predictors of Weapon System Acquisition Program Success

by

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A Statistical Analysis of the Effectiveness of Program Initial Conditions as Predictors of Weapon System Acquisition Program Success

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I. INTRODUCTION

The recent draft of a revision to Department of Defense (DOD) Directive 5000.1 suggests that the Pentagon is moving into a new era of program management. The groundwork for this revision to David Packard's earlier attempt to establish a firm policy base for the DOD procurement has been well laid by the reports of the Commission on Government Procurement and the Acquisition Advisory Group, and by Office of Management and Budget Circular A-109. This modification of Directive 5000.1 places greater emphasis on the necessity to evaluate proposed new weapon systems on the basis of reconciled mission needs and requires an acquisition process in which alternative concepts/solutions are investigated in detail. The degree of program oversight by the Office of the Secretary of Defense (OSD) as proposed has been increased by the addition of another decision milestone, "DSARC O", at which point the initiation of the conceptual effort will require Secretary of Defense approval.

Faced with mounting public pressure for greater control of costs and performance following some notable examples of forecasting errors like the C-5A and LHA programs, DOD appears to have responded by striving to exorcise every possible bit of uncertainty from the conduct of weapon system acquisitions prior to the committment of major resources. The desired result would be the procurement of systems which satisfy basic operational requirements by a

firm date and at a reasonable and predetermined price.

Although written several years prior to the proposed policy update, J. Ronald Fox's words have an 'I've-seen-it-all-before' air to them as he comments in Arming America on the changing patterns of military acquisition management.

> Since 1969 there have been further attempts to improve other aspects of weapons acquisition management. These include the establishment of "milestones" for major programs (i.e., dates for the accomplishment of crucial program objectives); the synchronization of management personnel changes with program milestones; a reduction in the numbers of letters of contract; the improvement of training programs for program management officials; a formal review procedure for each new weapon system's operational specifications. The object of the review would be to insure that program requirements are reasonable and attainable, and that prototype systems are developed and tested <u>before</u> a production program is approved. Serious doubts about the successful implementation of this proposal have troubled Defense Department observers, however. . .Many procurement officials in the Defense Department are, after all, aware that the present system has faults. But despite a steady succession of studies and recommendations, the procurement process has remained impervious to structural reform.[1]

Certainly only time will prove Fox right or wrong, but there is some evidence submitted by OSD that cost control has at least received greater attention among the major programs.[2]

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[1] Fox, J. R., <u>Arming America</u>, p. 456, Harvard University Press, 1974

[2] In a memorandum originating in the Office of the Director, Planning and Evaluation (OSD) dated 9 August 1976, it was reported that weapon system cost growth had declined generally in the last twelve months.

The purpose of this study was twofold. The first was to establish an historical perspective of major programs reaching fruition in the early to mid-1970's which will provide a means of comparison for future studies of program success, and thus perhaps support Fox's view. While the meaning of "program success" might well vary, it is here defined as the degree to which a program met initial estimates of cost, schedule and performance criteria. The first goal was met essentially by listing those programs studied with their associated degrees of success in Appendix C.

The second desired result was to investigate the validity of certain hypotheses about program management. Specifically, the approach taken in this case was to highlight gross differences in program outcomes on the basis of shared program characteristics, such as program size, initial funding and technical advance. Associated with this aim was an extensive correlation analysis in which the predictability of program success was determined from program initial conditions when certain variables such as service sponsor, weapon system type and life-cycle phase were controlled.

A. UNCERTAINTY IN WEAPONS SYSTEM DEVELOPMENT

A. W. Marshall and W. H. Meckling of the Rand Corporation addressed the problem of the predictability of cost, schedule and performance estimates associated with development programs in a report prepared for the U. S. Air Force in 1959.

Their conclusions regarding the uncertainty of new developments were:

1. Early estimates of important parameters are usually quite inaccurate in two respects. First of all, they are biased toward overoptimism, and secondly, their error is subject to a large variation.

2. The accuracy of estimates is a function of the stage of the system life-cycle at which time the appraisal was made.

The authors suggested a relationship between developmental estimates and the military world of R&D decision making, but little if any analysis was provided in their report other than to say that a problem in the way estimates are generated does exist. Also, the number of programs reviewed appeared rather small (22) and they were all Air Force sponsored.

Following the above report was the work of M. J. Peck and F. M. Scherer, The Weapons Acquisition Process: An Economic Analysis which was published in 1962. This bellwether study of the business of arms procurement improved noticeably on Marshall and Meckling's efforts to gain an understanding of the unpredictable nature of weapons acquisition.

> A major thesis of this study is that the weapons acquisition process is characterized by a unique set of uncertainties which differentiates it from other economic activity. To be sure, uncertainty is a pervasive feature of all economic activity,

> and most of the uncertainties in weapons acquisition have their commercial counterparts. But there is a uniqueness in both the magnitude and diverse sources of uncertainty in weapons acquisition.[3]

The operational definition of uncertainty was provided by the authors as "the relative unpredicatability of the outcome of a contemplated action".

Herein lies a problem which has confronted those researchers who have attempted to subject the success of program outcomes to statistical analysis based upon a comparison of initial estimates and demonstrated performance. Peck and Scherer summarized the difficulty in this way.

> Let us begin by attempting to ascertain the degree to which the outcomes of weapons programs are predictable. A rough measure is obtained by examining three crucial kinds of weapons program outcome predictions: (1) quality, or the expected technical performance and the reliability of the resulting weapon system; (2) development time, or the interval between the start of a development effort and the availability of operational weapons; and (3) the cost of development. Characteristically, predictions of these variables are made by contractors and/or buying agencies early in a weapons program and are recorded in written documents. The predictability of the variables can be determined by comparing the early predictions with actual quality, time and cost outcomes.
>
> Nevertheless, comparisons of this sort are properly viewed with considerable reservation, for there are extreme difficulties in obtaining satisfactory data. Neither the original estimates nor the final outcomes are completely comparable between programs, nor are they even necessarily representative of the true state of affairs within a given program.[4]

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[3] Peck, M. J. and Scherer, F. M., <u>The Weapons Acquisition Process: An Economic Analysis</u>, p. 17, Research Division, Graduate School of Business Administration, Harvard University, 1962

[4] Ibid., p. 19

The reasons given did overlap to an extent with those reported by Marshall and Meckling.

1. Initial predictions were made at varying points in the maturity of different programs.

2. Initial estimates were optimistically low and in some cases deliberately inaccurate.

3. Performance outcomes could not be measured quantitatively.

4. Time of availability outcomes were qualitatively assessed.

5. Cost outcomes were blurred by arcane bookkeeping procedures, whereby developmental costs were buried in production expenditures or post-production support.

In a criticism of the Selected Acquisition Report (SAR), the Blue Ribbon Defense panel questioned the validity of before-and-after comparisons futher.

> The basic approach to the SAR is the establishment of a baseline of estimated costs, schedules and technical performance, and the subsequent measurement of the present status against this baseline. . .Successfully predicting the course of development of a new weapon system is uncertain at best. The long period of time involved introduces unpredictable changes as outside events and circumstances shift during the five to nine years it usually takes to acquire a new weapon. The development process itself contains hidden unknowns. The original estimates of cost, schedule and technical performance of a weapon system can be made with considerable skill and with total honesty, but they remain only estimates, the worth of which can be determined only by the future unfolding of events. The SAR's tend to treat the original estimates as accurate predictions and to measure subsequent events in the development against the standard of the original estimates. There are two serious consequences of this procedure.

> ...The overwhelming concentration now appears to be on maintenance of the costs and schedule within the original estimate. Concern with the quality of the weapon and its ability to perform an essential mission are not presented in the SAR. . .Inhibition against change is the second serious consequence of the present SAR system.[5]

The picture is not so bleak as one would be led to believe. Peck and Scherer pointed out the other side of the ledger as well in their analysis of the processes of weapons development.

> To examine the effectiveness of weapons program execution in an operational way requires a meaningful criterion of effectiveness. One possibility is to evaluate actual time, cost and quality results against original predictions. In particular, original time, cost and quality predictions do not necessarily reflect optimal choices. Still, the analysis of variances from original predictions has several values. For one, it is useful method of pinpointing the problems which affect program outcomes. Furthermore, to the extent that major national security decisions are made on the basis of original predictions, sizeable variances from those predictions may imply a serious misallocation of resources.[6]

A greater implication of the position that comparative studies are of no utility is that without comparisons, the effectiveness of reforming activities within the weapon system acquisition process must be left entirely to intuition.

Peck and Scherer did attempt to pinpoint problems affecting program outcomes by correlating Marshall and Meckling's criteria of program success with a largely qualitative

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[5] Blue Ribbon Defense Panel, Report to the President and the Secretary of Defense on the Department of Defense, Vol. 1, p. 125, U.S. Government Printing Office, 1970

[6] Peck, M. J. and Sherer, F. M., The Weapons Acquisition Process: An Economic Analysis, p. 428, Research Division, Graduate School of Business Administration, Harvard University, 1962

collection of explanatory variables. The results were characterized by a lack of statistical significance which might be explained by a reliance on parametric procedures. However, the results did indicate that definite relationships existed between program characteristics externally imposed on the project, such as urgency, the importance of minimizing costs, state-of-the-art exploitation and program results.[7]

This study was conceived in part as a redirected continuation of the above aspect of Peck and Scherer's work; redirected in the sense that the choice of independent variables was limited to quantitative measures of a program (e.g., unit cost, total program cost, development expenditures and program length) which were then applied to a larger sample of programs using nonparametric analyses. However, more importantly this thesis has attempted to ascertain the validity of certain general beliefs of the nature of program management and its effect on program outcomes. Four separate hypotheses have been presented, each in its own right questioning the predictability of project success when considered as the result of a single determinant variable.[8] In short, the thesis has erected a model of the acquisition process in which the management skills and

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[7] Peck, M. J. and Sherer, F. M., The Weapons Acquisition Process: An Economic Analysis, ch. , Research Division, Graduate School of Business Administration, Harvard University, 1962

[8] A fifth hypothesis was posed to test the data source for bias.

practices of a system's program office staff or individual manager have been ignored as predictors of program results. The model was further refined by suppressing the externally imposed noise of program contractions (expansions) and economic escalation. The hypothesis testing served to illustrate one dimensional differences in acquisition programs (i.e., cost growth differences in programs differentiated by project cost alone).

In addition, a series of correlation tests were conducted in which the fundamental differences in program outcomes were further tested by controlling additional program characteristics such as service sponsor or weapon system type. The purpose of the correlation was twofold, first to establish whether the controlling process accented the gross differences identified by the hypothesis testing, and secondly, to identify among the program facets of size, length and risk, effective predictors of program outcomes.

II. METHODOLOGY

A. SELECTED ACQUISITION REPORT

Recognizing the problem of how program maturity may distort the accuracy of early forecasts, it was considered essential that some instrument adjust initial estimates for all programs to a common beginning, and also to allow for the adjustment of these forecasts in the light of a lengthy program life. Such an instrument was the Selected Acquisition Report (SAR).

The SAR serves as a comprehensive, summary acquisition status report for the "highest levels of management within the Department of Defense and (is) the basis for reports to the Congress and other government agencies including the Government Accounting Office (GAO)".[9] Compiled at the close of each quarter, the SAR tracks the success of each major weapons system acquisition in the areas of cost, technical performance and schedule.

In each of these areas, the report offers a comparison between current estimates for program success and the development, or initial, estimates. Sandwiched between these two expectations is yet a third, the approved program estimate which in practive varies only slightly, if at all, from the development estimate. The development estimate is established

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[9] Secretary of the Navy Instruction 7000.3

once the Secretary of Defense grants his approval for the program to move into full scale development, and generally has as its basis the Decision Coordinating Paper (DCP). The development estimate for procurement may be reviewed once the production contract has been let, but otherwise, the estimate may not be changed without permission of the Assistant Secretary of Defense (Comptroller). Fox points out the necessity of this last requirement as he quotes a DOD review of management control practices.

> This problem has been common enough to acquire the esoteric but descriptive label, "the rubber baseline". Translated, this means that the contractor managers would periodically make retroactive adjustments to cost estimates and schedules so that plans would equal actuals. . .Obscuring overruns in this fashion contributed to our being caught short on funding for two major programs last fiscal year.[10]

The approved program estimate is also based upon the DCP, or in its absence, a Program Memorandum or Program Change Decision. As these formal statements of changes in program goals are forthcoming, the estimate will necessarily be revised. The current estimate represents the program manager's most realistic assessment of program status. As the program matures, this appraisal will more and more equate to demonstrated performance or the actual completion of schedule milestones. The 31 March 1976 SAR for the A-7E project is provided as an example in Appendix A.

The 30 June 1976 SAR was the principal, primary reference

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[10] Fox, J. R., Arming America, p. 413, Harvard University Press, 1974

source of project data for this thesis. In fact, because of the completeness of the report and the clarity of its format, whether or not an acquisition program was included under the reporting system determined whether that program would be included in the analysis. Thus, this determination excluded a number of weapon systems presently in either development or procurement, principally in the areas of electronic countermeasures and naval gunnery.

B. ANALYTIC METHODS

1. Hypothesis Testing

1. Large programs have a tendency to incur greater cost and schedule growth in absolute and relative terms than do smaller programs.

One of the initial, underlying assumptions of this thesis was that not only will weapon system acquisitions experience cost growth, but that for system with large program costs, the growth will be correspondingly greater than for those less expensive projects. Reasons for the explanation of the cost growth phenomenon have been postulated again and again by critics of military procurement (e.g., Peck and Sherer, Fox). Not the least frequently observed reason is that of over-optimism. It would seem reasonable that large, expensive programs would require a certain amount of "selling" on the part of sponsors to ease the difficulties of higher level DOD and Congressional approval. This "selling" often took the form of understating the eventual program cost, and with

it the technological risk involved in the development, not to mention the date on which the system enter service. Whether overoptimism was the result of deliberate policies on the part of the sponsoring agency is something of a moot point. Peck and Scherer, however, did point out that the practice has been accepted as a matter of fact within the defense industry.

> Quite commonly, this strategy includes submitting proposals which in one or more aspects are highly optimistic. Indeed, the propensity to 'but into' attractive new programs with optimistic quality, time, and/or cost estimates is perhaps as much as an industry practice in advanced weapons acquisition as list price cutting is in automobile retailing, or as the advertising of loss leaders is in department store operations.[11]

Concurrent with the overoptimism that acompanies large programs, it was presumed that there would be difficulties encountered in the area of cost control simple because of program size, an extension of the belief that with size one inherits waste and a certain amount of uncontrollability. Unfortunately, it is impossible to distinguish explicitly between optimism or waste based on data gathered from the SAR's.

2. <u>Programs with a larger development phase budget have a greater tendency to achieve initial cost, performance and schedule estimates</u>.

An acedemic approach to the study of project management has stressed the importance of "front-end loading" the acquisition

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[11] Peck, M. J. and Scherer, F. M., The Weapons Acquisition Process: An Economic Analysis, p. 413, Research Division, Graduate School of Business Administration, Harvard University, 1962

effort, citing the lever effect which early commitment of funds has upon program performance.[12] It would appear reasonable that programs which enjoy an extensive development period would suffer the least uncertainty in the expected level of program outcome, since a greater percentage of the "unknowns" which plague any program would be uncovered.

3. Programs with greater technical risk tend to incur greater cost and schedule growth than do less risky programs.

This hypothesis is associated with the second contention in that programs which represent a great deal of technical risk, which require a more complex and sophisticated technical effort (as perceived from the outset of the program), would be more susceptible to failure.

4. Multiple-source contracted programs enjoy an advantage in program success over sole-source contracted programs.

For the purpose of this analysis, those programs which had more than one prime contractor regardless of whether the systems were in procurement or development were considered multiple source programs. In the case of air-craft systems, if there were competing contractors for either the airframe or engine designs, the program was considered to have a "second source". Frederick Sherer in his study of the economic incentive in the weapons system acquisition process

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[12] The effect was originally suggested to this student by Professor Melvin Kline, U. S. Naval Postgraduate School.

documented the significant cost reductions which developed during the joint production of military aircraft in World War II. Although not in as much detail as Scherer, Fox touched upon the benefits of "second sourcing", reporting that "it would be reasonable to assume a 25% reduction in contract price can be achieved in many, if not most, cases when competition is introduced."[13] It would appear that this is one area in which weapons procurement responds to traditional market forces. The fourth hypothesis seeks to determine first, whether the evident cost successes do exist in a significant number of cases, and second, whether the advantage of multiple-source contracting is extended to the areas of performance and schedule.

5. <u>The prospect of program success dimenishes with increasing maturity among programs</u>.

This last hypothesis was posed in order to test the validity of the SAR in overcoming the criticisms alluded to earlier about the noncomparability of programs in differing stages of their life-cycle. For example, early in the life of a program, before the realities of the management or technical task at hand are more apparent, one would expect that current estimates of project outcomes would agree with initial assessments. But, as the program achieves greater maturity, and uncertainties arise, the gap between the two expectations

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[13] Fox, J. R., <u>Arming America</u>, p. 256, Harvard University Press, 1974

would be sure to widen.

Each hypothesis was tested using a one-tailed Mann-Whitney U Test (a nonparametric one way analyses of variance) in which the means of program outcomes were compared. For the most part, the sample of 48 programs would be divided along the median of the program variable in question, except in the case of the fifth hypothesis where whether a program was in development or procurement became the classifying criterion. The results of these tests are presented in Chapter III.

2. Correlation

As stated earlier, associated with the hypothesis testing was a desire to examine the correlation between the output variables of cost, performance and schedule, and initial program estimates of program length, cost and technical risk when specific program characteristics were controlled for explicitly. The thesis employed a nonparametric correlation proceudre offered as a subprogram in SPSS: Statistical Package for the Social Sciences by Norman H. Nie, et al. The following characteristics were considered and controlled for in deriving correlations between program outcomes and initial estimates:

1. All forty-eight programs together without any differentiation;
2. Programs differentiated by the maturity of their design (i.e., whether the program was in development or

had advanced to procurement);

4. Programs differentiated by system type, ship, aircraft, missile or miscellaneous (tracked vehicles, fire-control systems, etc.);

5. Programs differentiated by service sponsor, Navy, Army, or Air Force.

The first category of 'undifferentiated programs' was included as a control feature to serve as a means of comparison for the following four program characteristics. Items two and three were included as part of follow-up tests to the verification of the fourth and fifth bypotheses. The last two program characteristics, system type and service sponsor, were included because they are frequently used as means of ordering weapons systems. Also, there are substantial inter-service differences in system acquisition, and as a result, there are natural, virtually instinctive inclinations to make comparisons between the programs of each service.

Additionally, the intercorrelations among program outcomes were examined to see if any light could be shed on the trade-offs between cost, performance and schedule. The correlation results are presented in Chapter III.

C. SELECTION OF INDEPENDENT VARIABLES

1. Program Cost

For the purpose of the analysis, it was considered essential that each of the forty-eight programs be considered

on an equal footing, that is, considered from the same base year. In this way, comparability between programs on the basis of total program cost would be maintained. The base year selected was 1974 since all but two programs (added late in the thesis) predated that year. Each of the programs reported development estimate program costs in their own base year dollars, which in turn were converted to 1974 dollars. The method of accomplishing this conversion was not very satisfactory, but had to suffice for lack of a superior alternative. From a Direct Budget Plan (TOA) History for the Department of the Navy, an implicit price deflator for the fiscal year 1964 through 1977 was derived. The unsatisfactory aspects of this source are evident when one considers that the TOA history included nonprocurement appropriations such as OM&N as well as the procurement related appropriations, RDT&E, SCN, etc. The U. S. Bureau of Economic Analysis is in the process of determining deflators for each of the basic defense industries, but results will not be forthcoming until late 1977.

A copy of the TOA history and an example of the manner in which the implicit price deflators for each of the program base years was derived is provided in Appendix B.

2. Program Unit Cost

Unit cost was selected as an independent variable on the assumption that program success (primarily in the area of cost) could not be adequately explained by program

size alone. For example, a program line the A-7E in which the Navy is procurring a proven aircraft design with updated avionics, and the F-14A program which represents a completely new weapon system, could have conceivably identical program costs provided sufficient quantities of the A-7E were purchased. However, the true nature of both programs would be obscured. Of the two, clearly the F-14A with a program unit cost of $16.8M (1974$) is the more ambitious undertaking, and the lesser unit cost of the A-7E, $4.1M in 1974 dollars, would reflect this. As in the case of program cost, development estimates of unit costs were translated into 1974 dollars.

3. Development Investment

The development investment for each program was derived as the ratio of the level of development spending to total program as foreseen at DSARC II. No judgement of the manner of (or purpose for) development spending was attempted. The variable was intended to serve as a complement to program unit cost, that is, a measure of the technological advance of the project. Some difficulties were encountered in those reports for nuclear powered men-of-war where propulsion system development costs attributed to both the Navy and the Energy Research Development Agency (ERDA) were not included in the cost section of the SAR's, but rather in a SAR addendum. Consequently, at first glance a project as large and complex as NIMITZ

(CVAN 68) appears to be an off-the-shelf product, despite the fact that her two reactor propulsion plant represents a first for the surface Navy and is hardly a trivial technological step. Adjustments were made for cases such as this by adding the additional estimated development cost to both the level of development funding and the total program cost.

4. Program Length

Of all the explanatory variables, time was the most subjectively determined. Initial program length, measured ostensibly from the initiation of the project to an initial operational capability date (IOC) proved to be a bit troublesome to extract from the SAR's. Earlier researchers have encountered similar problems.

> Time of availability predictions are often made in terms of an 'initial operational capability' - a decidedly qualitative concept. Does one missile on a lonely launch pad constitute an 'initial operational capability'? Or do 30 missiles when their reliability in time of need is doubtful?[14]

Fortunately, the term IOC is a common one within DOD and in a large number of cases, those dates were reported explicitly. In the case of Navy shipbuilding programs, a simplifying rule was established whereby the date on which the lead ship of the entire class in question became available for

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[14] Peck, M. J. and Scherer, F. M., The Weapons Acquisition Process: An Economic Analysis, p. 20, Research Division, Graduate School of Business Administration, Harvard University, 1962

operational deployment was chosen arbitrarily as the "IOC" date. There are obvious draw-backs to this method when the entire class is considered as any student of ship construction can point out. Namely, the greatest schedule slippages often occur during follow-ship production. Still, the availability of the lead ship does represent the realization of a design, and in order to maintain some parity with other systems produced more rapidly, the consistency of the above method was considered essential.

The other end-point of program length, the initiation of the project, was even more difficult to determine. In most cases, a date corresponding to the advent of the system life-cycle was selected as the starting point. More often than not, this date was the date of approval for the system requirements/characteristics. There was a distinct lack of uniformity noted among the various programs in the reporting of this schedule milestone. In a few cases programs were considered underway with an all inclusive 'commenced engineering development' or 'initiated validation phase'.

D. SELECTION OF DEPENDENT VARIABLES

1. Cost Growth Factor

Fortunately, a recent revision of the SAR system directed that development and current cost estimates be reported in constant year dollars as well as in escalated figures. This change has made the pinpointing of true cost growth that much easier. It came as something of a shock

to discover that little or no provision for escalation was included in the development estimate of many programs. Where some accounting for escalation was made, invariably the inflation rate was unrealistically low.

The office of the Assistant Secretary of Defense (Comptroller) publishes a "SAR Program Acquisition Cost Summary" (see Appendix C) once each quarter's collection of individual reports is complete. From this summary it is possible to determine each program's cost growth both in dollars and as a percentage of original estimates. In each instance, the resultant figures are adjusted by OSD analysts to negate the effects of inflation and program quantity changes. Unfortunately, the relative measure of program cost growth is related definitionally to the original program cost estimate as shown below.

$$\text{Cost growth (\%)} = \frac{\text{Cost Changes}}{\text{Development Estimate + Quantity Changes}}$$

(All entries are in base year dollars)

One would expect a negative correlation between cost growth (%) and program size, expressed above as the 'development estimate'. The extent of the correlation would depend on the degree to which the Cost and Quantity Changes varied with total program cost. To aid in clarifying the effect of program size on cost success, it would be helpful to have the assistance of an absolute measure of growth, namely Cost

Growth ($) which is the dollar value of the overrun. This measure is determined as shown below.

$$\text{Cost Growth (\$)} = \text{Cost Growth(\%)} - 1 \times \text{Development Estimate}$$

Hence, a negative "growth" would indicate an underrun.

2. Performance Achievement Factor

Navy and Air Force concepts of system effectiveness were presented in the 1960's as a measure of how well a system performed its intended function. This figure of merit was derived originally as a companior to cost effectiveness in the hope that together the two would serve to determine whether a system undergoing design would satisfy most efficiently those operational requirements which spawned it in the first place. Despite interservice differences in the wording of what was meant by system effectiveness, the measure (expressed as a probability) was generally conceeded to have three basic components;

1. the performance capability of the system;
2. the operational readiness or availability that is, its ability to start performance of a mission when called upon to do so;
3. the continued capability of the system to perform, or its mission reliability or dependability.

In time however, it became apparent that models of system effectiveness were not as useful as originally conceived.

The computations were messy and highly subjective. For example, how much does the failure of a single component degrade the effectiveness of a system? Or even more basic, what constitutes a failure? Since the derived probabilities were by no means "hard numbers", they were mistrusted by managers, and the computational aspects of system effectiveness fell into disuse.

Given that an evaluation of system performance is essential to any analysis of program success, and in the absense of a readily available performance factor counterpart to cost growth, a simplistic method of marking performance using the three basic elements of system effectiveness where possible was devised. From SAR data on the technical/operational characteristics of the system in question, it was possible to contrast current estimates of system performance with development estimates. Generally speaking, the performance achievement factor was determined by assessing a weighted average of major performance areas such as speed, time-on-station, maintainability, system accuracy, etc. A value of performance less than 1.0 indicates that the system achieved better results than originally estimated. An example of how this computation was made is provided in Appendix C.

3. Schedule Overrun Factor

As in the case of attaining performance goals, the schedule overrun factor was determined by the ratio of current to development estimates of program length. However,

like cost growth (%), shcedule slippage (%) is related inversely to program length.

$$\text{Schedule slippage}(\%) = \frac{\text{Actual (Current Estimate Of) Program Length}}{\text{Development Estimate of Program Length}}$$

Hence, a negative correlation would be expected. To minimize this dependency, a fifth output variable, schedule slippage (months) was introduced. In a similar fashion as cost growth ($), this variable measures the actual slippage of the IOC data in months.

III. RESULTS

A. HISTORICAL PERSPECTIVE

Appendix C has listed those programs from which program data was obtained for the analysis. With the exception of POSEIDON, all the programs are currently included under the SAR system. (POSEIDON reports were terminated in June 1975 following completion of system deployment and the subsequent disestablishment of the program office). For the convenience of the reader, the programs are ordered by service sponsor. An examination of the outcome means for each service indicates that perhaps Navy programs enjoyed a greater achieved performance at greater cost and shcedule growth than did Army and Air Force projects. A sample comparison between outcome means revealed that the NAVY - USAF differences in all three categories were significant, while the pertinent ARMY - NAVY disparity was limited to the area of cost alone.

The results of the NAVY - USAF comparison are not fully understood. Sample comparisons of Navy programs (less ship systems) and the Air Force projects shown did result in less significant cost differences. Additionally, when missile systems (which historically have proven to be technically more successful than other system types) were excluded from both samples, the performance difference between services was still evident. No explanation for this is readily apparent, nor was there any system type peculiar to a single service that could account for the Air Force advantage

in meeting deployment schedules

B. HYPOTHESIS TESTING

1. Large programs have a tendency to incur greater cost and schedule growth than do smaller programs.

Table 3-1 displays the difference in the means of program outcomes between large and small projects. The column marked 'significance' indicates the degree to which the differences were statistically significant. In instances of no significance, the column entry is NS. Subsequent tables in this section are arranged similarly.

TABLE 3 - 1

COMPARISON OF PROGRAMS BASED ON PROGRAM SIZE

LARGER PROGRAMS		SIGNIFICANCE	SMALLER PROGRAMS	
Cost Growth(%)	1.13	0.003	Cost Growth(%)	1.29
Performance	0.99	NS	Performance	1.00
Schedule Slip (%)	1.16	0.005	Schedule Slip (%)	1.44
Schedule Slip (Mos.)	12.6	0.005	Schedule Slip (Mos.)	25.2
Cost Growth($)	534.0M	0.006	Cost Growth($)	163.7M

The results appear to provide mixed support for the first hypothesis. Ignoring the differences in relative cost growth for reasons given in Chapter II, note the differences in schedule overrun. Historically, larger programs have done significantly better in meeting original schedules, both in

a relative and absolute sense. The lack of significance observed in the area of achieved performance is a result that will be repeated elsewhere in this chapter. Overall, the nonparametric analyses of variance were ineffectual in accounting for the variance in system performance.

In the area of cost growth($), larger programs did not appear to hold the line against overruns. The reasons for this may have included a tendency for the managers of large (and therefore important) programs to throw money at problems, particularly schedule problems, until a solution is found. Once a major program has been funded, rarely has it had to do without additional resources if required.

2. <u>Programs with more development funding have a greater tendency to achieve initial cost, performance and schedule estimates</u>

TABLE 3 - 2

COMPARISON OF PROGRAMS ON BASIS OF LEVEL OF DEVELOPMENT FUNDING

HIGHER PROGRAMS		SIGNIFICANCE	LOWER PROGRAMS	
Cost Growth(%)	1.15	0.040	Cost Growth(%)	1.27
Performance	0.99	NS	Performance	1.00
Schedule Slip (%)	1.24	0.002	Schedule Slip (%)	1.42
Schedule Slip (Mos.)	15.94	NS	Schedule Slip (Mos.)	21.7
Cost Growth ($)	459.9M	NS	Cost Growth ($)	234.7

Perhaps the most important comparison in Table 3 - 2 is that which contrasts relative cost growth. During the analysis of program data, a very high (0.750-1.000) positive correlation was found to exist between program cost and development funding in a significant number of cases. It was likely that the two were measuring essentially the same characteristic, program size. Thus, one would expect Tables 3 - 1 and 3 - 2 to bear a resemblance to one another. In terms of relative cost growth and schedule slippage, this similarity exists. What is crucial about the results of this second sample comparison is that the level of development funding has a significant negative impact on relative cost growth. Bearing in mind that the development cost is also an indirect measure of program size, this is the first instance of an indication, not confounded by definitions of the variables, that suggests program size may inhibit the degree of cost growth. Further signs of the efficacy of early and substantial investments are the differences in relative schedule slippage and the absence of any significance to the difference between the absolute cost growth for each sample.

3. <u>Programs with perceived technical risks tend to incur greater cost and schedule growth than do less risky programs</u>

TABLE 3 - 3

COMPARISON OF PROGRAMS ON
BASIS OF DEVELOPMENT INVESTMENT

HIGHER PROGRAMS		SIGNIFICANCE	LOWER PROGRAMS	
Cost Growth(%)	1.18	NS	Cost Growth(%)	1.24
Performance	0.97	NS	Performance	0.97
Schedule Slip (%)	1.32	NS	Schedule Slip (%)	1.33
Schedule Slip (Mos.)	19.4	NS	Schedule Slip (Mos.)	18.2
Cost Growth($)	349.8M	NS	Cost Growth($)	340.3M

The weakness of development investment as a explanatory variable is apparent in Table 3 - 3. No significance can be attributed to the difference in outcomes between programs with a higher development/committment and those with less. A second comparison between the extremes of each group, the highest and lowest quartiles, was made with similar null results.

4. <u>Multiple-source contracted programs enjoy an advantage in program success over sole-source contracted programs</u>

TABLE 3 - 4

COMPARISON OF PROGRAMS ON BASIS OF PRODUCTION/DEVELOPMENT SOURCES

SOLE-SOURCE		SIGNIFICANCE	MULTIPLE SOURCE	
Cost Growth(%)	1.21	0.040	Cost Growth(%)	1.14
Performance	0.99	NS	Performance	1.02
Schedule Slip (%)	1.30	NS	Schedule Slip (%)	1.44
Schedule Slip (Mos.)	17.8	NS	Schedule Slip (Mos.)	24.7
Cost Growth($)	382.3M	0.049	Cost Growth($)	103.4M

The findings of Peck and Scherer were sustained by the Mann-Whitney test. In terms of relative and absolute cost growth, second-source programs did better than their sole-source counterparts. Although a small class of projects (7), the multiple source programs included Army and Navy projects of all system types. In regard to the achieved performance of both program types, this study found no significance in the difference of program outcomes. This is at variance with the findings of Rubin and Marquis' who determined that "sole source contractors do significantly better technically than contractors who were selected by some form of competitive procedure."[16] Rubin and Marquis' study is not precisely comparable to the

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[16] Sloan, Alfred P., School of Management, Massachussetts Institute of Technology, Report #192-66, Critical Decisions in the Initiation of Development Projects, Rubin, I. M. and Marquis', D. G., June 1966

one undertaken here in that only development projects in which the technical performance was evaluated subjectively by management and engineering personnel, were considered. However, the contention that greater technical performance can be achieved in the absence of competition was not supported.

5. The prospect of program success diminishes with increasing maturity among programs

TABLE 3 - 5(A)

COMPARISON OF PROGRAMS BASED ON LIFE-CYCLE DIFFERENCES

PROGRAMS IN PROCUREMENT		SIGNIFICANCE	PROGRAMS IN DEVELOPMENT	
Cost Growth(%)	1.22	NS	Cost Growth(%)	1.18
Performance	0.98	NS	Performance	1.00
Schedule Slip (%)	1.33	NS	Schedule Slip (%)	1.29
Schedule Slip (Mos.)	18.7	NS	Schedule Slip (Mos.)	17.5
Cost Growth($)	460.6M	0.012	Cost Growth($)	213.9M

Table 3-5(a) reveals that on a gross level the SAR is able to minimize the differences among programs that arise because of life cycle disparities. With the exception of program growth in dollars, programs in procurement and those still in development exhibited similar success. The exception of program growth is indicative that either uncertainties in schedule or producibility do still exist, and that the

development phase has not been completely successful in identifying and costing these aspects of the system. It is felt that the lack of significance between the two categories can be attributed to allowing the SAR development estimate to be reviewed and updated when required once a production contact has been let.

In the event that differences within groups were obscured by combination, the development and procurement classes were again divided, in the development cast by the age of the program, and in the case of procurement by whether the system had reached IOC. These two groups were then compared and the results presented in Table 3-5(b).

TABLE 3 - 5(B)

COMPARISON OF PROGRAMS BASED ON LIFE-CYCLE DIFFERENCES

PROGRAMS AT/PAST IOC		SIGNIFICANCE	RECENTLY INITIATED PROGRAMS	
Cost Growth(%)	1.22	NS	Cost Growth(%)	1.16
Performance	0.96	0.025	Performance	0.99
Schedule Slip (%)	1.29	NS	Schedule Slip (%)	1.35
Schedule Slip (Mos.)	16.4	NS	Schedule Slip (Mos.)	24.1
Cost Growth($)	523.8M	0.050	Cost Growth($)	266.5M

The results were generally supportive of those shown in Table 3 - 5(a). Once again the difference in cost growth is significant; however, the difference in the means of

achieved performance was unexpected. One possible explanation is that the realities of a fully operational deployment might test system capabilities better than a formal evaluation period, principally in the important areas of reliability and maintainability. On balance, the findings in Tables 3 - 5(a) and 3 - 5(b) supported the contention that the SAR in its present form does overcome sufficiently the difficulties in comparing programs at various stages of completeness.

C. CORRELATION

The results of the nonparametric correlation are presented in Tables 3 - 6 through 3 - 10(c). Overall, the results are not impressive. To be sure, there were individual cases in which the controlled characteristic produced effective results. For example, missile programs displayed an across-the-board effectiveness in predicting success. (See Table 3 - 7(b)). Why this is true of missile systems and not ships is not readily apparent. For whatever reason, there is a greater homogeneity among missile programs than among other groupings. Perhaps then, one could suggest that greater faith could be placed in the initial estimates of missile program success to the extent that they are valid indicators of future results. Characteristic, however, of the analysis was the finding of less than 50% of the correlations as significant. And, when those variable pairs with definitional relationships are discounted, the results are even more

nebulous. Additionally, the whole purpose of ordering systems by some specialized criterion variable to isolate the effects of program determinants is called into question when one recognizes that the category of "all programs" exhibited a greater number of significant correlations than a majority of the other instances when a program characteristic, like service sponsor, was controlled. Actually, the taxonomic analysis was weakened further by disparities in sample size among some of the classes of programs. The greatest difference was noted between the sole-source contracted programs (40) and multiple-source contracted programs (7). It is not unexpected that those categories had by comparison more significant results than their smaller counterparts, since greater sample size lowers the level at which a relationship between variables can be deemed significant.

TABLE 3 - 6*

ALL PROGRAMS

	Performance Factor	Cost Growth Factor (%)	Cost Growth Factor ($)	Schedule Slip Factor (%)	Schedule Slip Factor (Mos.)
Program Unit Cost	0.1193	-0.2611 (0.038)	0.1430	-0.1668	-0.0682
Program Cost	0.1321	-0.3488 (0.008)	0.4549 (0.001)	-0.5408 (0.001)	-0.3892 (0.003)
Program Development Investment	0.0545	-0.1415	-0.0964	-0.0746	-0.0608
Program Length	0.2822 (0.027)	-0.2763 (0.032)	0.0999	-0.3898 (0.004)	-0.0664

* Entries in parentheses indicate level to which Spearman correlation is significant. All others are not significant.

Sample Size 48

Program Outcomes (Mean)

Performance	0.992
Cost Growth (%)	1.210
Schedule Slip (%)	1.326

TABLE 3 - 7(A)[16]

SHIP SYSTEMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	N/A	-0.3766	-0.5667 (0.056)	0.0678	0.5439 (0.065)
Total Program Cost	N/A	-0.7488 (0.011)	-0.4333	-0.627 (0.035)	-0.494 (0.088)
Development Investment	N/A	0.0890	-0.2447	0.4120	0.5297 (0.071)
Program Length	N/A	-0.3109	-0.4603	-0.1362	0.3613

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
9	1.000	1.220	1.308

TABLE 3 - 7(B)

MISSILE SYSTEMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	-0.[illegible]612	-0.3[illegible]05 (0.055)	0.2953	-0.4653 (0.022)	-0.3940 (0.048)
Total Program Cost	-0.0123	-0.4677 (0.025)	0.6017 (0.004)	-0.6889 (0.001)	-0.5570 (0.006)
Development Investment	0.0432	-0.5716 (0.007)	-0.1861	-0.3478 (0.072)	-0.4118 (0.040)
Program Length	0.4[illegible]71 (0.025)	-0.2992	0.4363 (0.040)	-0.7703 (0.001)	-0.4780 (0.022)

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
19	0.987	1.226	1.509

16 No correlations with achieved performance were possible because each each of the programs in the sample was assigned a factor of 1.0 .

TABLE 3 - 7(C)

AIRCRAFT SYSTEMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	-0.922	0.1694	0.3978 (0.078)	0.1046	0.0871
Total Program Cost	0.3709	-0.1606	0.5341 (0.025)	-0.1246	-0.0380
Development Investment	0.1554	0.2381	0.0551	0.5062 (0.032)	0.4285 (0.063)
Program Length	0.2001	-0.2090	-0.3055	-0.1357	-0.0112

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
14	0.991	1.149	1.145

TABLE 3 -7(D)

MISCELLANEOUS SYSTEMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	0.0	0.2000	0.5429	-0.5000	-0.1000
Total Program Cost	-0.1160	-0.0286	1.0000 (0.001)	-0.8000 (0.052)	-0.6000
Development Investment	0.2899	-0.0857	0.2571	-0.3000	0.1000
Program Length	-0.2500	0.2029	0.2899	-0.6667	-0.3591

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
6	0.998	1.170	1.170

TABLE 3 - 8(A)

SOLE-SOURCE CONTRACTED PROGRAMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	0.2001	-0.3363 (0.018)	0.1433	-0.1103	0.0243
Total Program Cost	0.2042	-0.3304 (0.020)	0.5929 (0.001)	-0.4943 (0.001)	-0.3401 (0.017)
Development Investment	0.0392	-0.1106	-0.0598	-0.0448	-0.0539
Program Length	0.2888 (0.037)	-0.1480	0.2477 (0.067)	-0.2710 (0.050)	0.0464

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
40	0.986	1.207	1.303

TABLE 3 - 8(B)

MULTIPLE-SOURCE CONTRACTED PROGRAMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	-0.2041	-0.6429 (0.060)	-0.2857	-0.5357	-0.3571
Total Program Cost	-0.6124 (0.072)	-0.4643	0.0357	-0.6429 (0.060)	-0.5714 (0.090)
Development Investment	0.6124 (0.072)	-0.2143	0.3571	-0.1786	-0.0714
Program Length	0.0	-0.4140	-0.1261	-0.6847 (0.045)	-0.5225

Sample Size	Performance	Cost Growth	Schedule Slip
7	1.023	1.140	1.443

TABLE 3 - 9(A)

PROGRAMS IN PROCUREMENT

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	0.0901	-0.4680 (0.008)	-0.2348 (0.079)	0.0462	0.1611
Total Program Cost	0.0619	-0.3233 (0.054)	0.4188 (0.017)	-0.6198 (0.001)	-0.5926 (0.001)
Development Investment	-0.1763	-0.2361	-0.1229	-0.4241 (0.014)	-0.0675
Program Length	0.3805 (0.028)	-0.2419	-0.0589	-0.3564 (0.037)	-0.1602

Sample Size	Performance	Cost Growth	Schedule Slip
27	0.976	1.225	1.333

TABLE 3 - 9(B)

PROGRAMS IN DEVELOPMENT

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	0.3953 (0.058)	-0.1508	0.3225	0.0270	0.0418
Total Program Cost	0.3298 (0.098)	-0.4071 (0.052)	0.4414 (0.033)	-0.4880 (0.023)	-0.0984
Development Investment	0.5151 (0.017)	-0.3656 (0.074)	0.0319	-0.1501	-0.0486
Program Length	0.3304 (0.098)	-0.3544 (0.081)	0.3790 (0.067)	-0.2931	0.1953

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
17	0.995	1.178	1.293

TABLE 3 - 10(A)

NAVY PROGRAMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	0.3760 (0.032)	-0.5484 (0.003)	-0.2130	-0.1329	-0.0185
Total Program Cost	0.2866 (0.032)	-0.6306 (0.001)	0.1304	-0.6177 (0.001)	-0.5712 (0.001)
Development Investment	0.0557	0.0187	-0.2331	-0.1079	-0.0922
Program Length	0.4317 (0.016)	-0.5273 (0.004)	-0.1628	-0.4471 (0.013)	-0.2337

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
25	0.969	1.272	1.404

TABLE 3 - 10(B)

ARMY PROGRAMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	-0.0305	-0.2992	0.0374	-0.1923	0.0
Total Program Cost	-0.1997	-0.3036	0.5604 (0.019)	-0.5110 (0.037)	-0.0718
Development Investment	0.0118	-0.3297	-0.3128	0.0826	0.2188
Program Length	0.2744	-0.1506	-0.1084	-0.6177 (0.012)	0.0501

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
14	1.025	1.149	1.292

TABLE 3 - 10(C)

USAF PROGRAMS

	Performance Achievement	Cost Growth (%)	Cost Growth ($)	Schedule Slip (%)	Schedule Slip (Mos.)
Unit Cost	0.1219	0.1167	0.4167	-0.0848	0.0509
Total Program Cost	0.3133	0.0	0.7333 (0.012)	-0.2034	-0.0170
Development Investment	-0.6659 (0.027)	0.1303	0.2678	0.1532	0.2383
Program Length	0.2283	-0.0952	0.5283 (0.091)	-0.0479	0.4072

Mean Outcomes

Sample Size	Performance	Cost Growth	Schedule Slip
9	1.006	1.141	1.160

Table 3 - 6 has displayed the correlation results for all forty-eight programs without any differentiation. The strength of program cost in determining schedule success is apparent by the significance levels of the correlations (0.001 and 0.003). Table 3 - 7 reveals the superiority of the missile system correlation over the other system types. Eleven out of eighteen valid correlations were significant in the case of missile programs, while ship systems produced but five. Oddly enough, aircraft systems with a larger sample size than ship systems had only four significant correlations. Apparently, aircraft systems were responding to other determinants, most probably managerial in origin.

Despite the great difference in sample size note previously, multi-source programs and sole-source programs produced very nearly the same number of significant correlations. (See Table 3 - 8). In the case of the second source programs, the lack of impact on the part of program cost on absolute cost growth noted earlier was suprising, thereby suggesting that cost benefits do occur as the result of competition. In common with multi-source contracted programs, developing programs reflected a decreasing level of performance with increasing technical risk. This expected result was curiously not demonstrated elsewhere. The differences between service programs discussed earlier are exhibited in Table 3 - 10. Not suprisingly, with a larger sample size, Navy programs produced more significant correlations than

either of the other services' programs combined.

Table 3 - 11 represents a summary of the statistically significant (0.100) tests presented in Tables 3 - 7 through 3 - 10, showing the degree to which variable relationships were common regardless of the controlled program characteristic. Similarily, Table 3 - 12 displays a summary of the correlation (not shown) of dependent variables with themselves and the degree of commonality encountered.

TABLE 3 - 11

SUMMARY OF SIGNIFICANT CORRELATIONS BETWEEN DEPENDENT/INDEPENDENT VARIABLES

Performance	Positive	Negative
Unit Cost	1	2
Program Cost	9	0
Development Investment	0	0
Program Length	4	0
Cost Growth (%)	**Positive**	**Negative**
Unit Cost	0	6
Program Cost	0	7
Development Investment	0	2
Program Length	0	3
Schedule Slip (%)	**Positive**	**Negative**
Unit Cost	2	0
Program Cost	3	1
Development Investment	2	0
Program Length	6	0
Schedule Slip (Mos.)	**Positive**	**Negative**
Unit Cost	0	1
Program Cost	0	10
Development Investment	1	1
Program Length	0	7
Cost Growth ($)	**Positive**	**Negative**
Unit Cost	1	1
Program Cost	0	7
Development Investment	2	1
Program Length	0	1

TABLE 3 - 12

SUMMARY OF SIGNIFICANT CORRELATIONS BETWEEN DEPENDENT VARIABLES

Performance	Positive	Negative
Cost Growth (%)	0	6
Cost Growth ($)	0	0
Schedule Slip (%)	0	0
Schedule Slip (Mos.)	0	0
Cost Growth (%)	**Positive**	**Negative**
Cost Growth ($)	10	0
Schedule Slip (%)	9	0
Schedule Slip (Mos.)	4	0
Cost Growth ($)	**Positive**	**Negative**
Schedule Slip (%)	1	2
Schedule Slip (Mos.)	1	2
Schedule Slip (%)	**Positive**	**Negative**
Schedule Slip (Mos.)	12	0

The results of the correlation analysis as summarized in the above tables illustrate some interesting points. The first of these is the weakness of the independent variable, development investment. Construed as a measure of technological risk, the variable failed to correlate with any of the outcomes except in a few cases. One of two conclusions can be reached, either the program charactersitic of risk is valid and the variable as defined did not capture it, or risk has little or no effect on program outcome. It is suspected that the former is true based upon the results

reported by Peck and Scherer.[17] Also, on reflection, it is felt that the data as presented in the SAR's could not be manipulated otherwise to measure risk.

Much the same criticism can be directed toward the use of program unit cost. With the exception of relative cost growth, unit cost did little to explain program outcomes. The fact that unit cost did correlate significantly with relative cost growth in six out of a possible twelve cases was unexpected. The variable was intended initially to support development investment as a measure of the complexity of the program. Intuitively one would expect that the relationship between unit cost and cost growth (%) to be a positive one, not negative. It is suspected that unit cost may be reflective of an unknown project feature.

From Table 3 - 12, a summary of the correlations between dependent variables reveals that a definite relationship between cost and schedule growth exists, perhaps more aptly put as "time is money". As in the case of the analysis involving both dependent and independent variables, performance achievement remained a largely unexplained outcome, although in 6 of 11 trials, a significant negative correlation between relative cost growth and performance was reported. It may be hasty to say that a desire to reach or surpass initial performance levels causes cost overruns since a

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[17] Peck, M. J. and Scherer, F. M., The Weapons Acquisition Process: An Economic Analysis, Chapter 16, Research Division, Graduate School of Business Administration, Harvard University, 1962

corresponding relationship between performance and cost growth in dollars was not evident. The overwhelming number of significant correlations between relative and absolute cost overruns, and schedule slippages must be discounted on definitional grounds.

D. CONCLUSIONS

From the results of the hypothesis testing, three major conclusions have been derived.

1. Contrary to previous belief, large, expensive programs exhibited a greater controllability in terms of schedule than did projects of smaller size.

One possible explanation is that large, expensive programs attract a great amount of attention from every quarter, the sponsoring service itself, OSD, Congress and the public. Conceivably, greater pressure are brought to bear to keep large programs within the limits of an original assessment as suggested by the Blue Ribbon Defense Panel, and thereby avoid the embarassment of adverse program outcomes. A second reason (and one not necessarily exclusive of the first) might be that large programs, because of their size and sensitivity, are subject to greater scrutiny before the projects get underway, and thus the original estimates are more realistic. Also, once underway, program offices may find themselves more adequately staffed both in numbers of people and their expertise to ensure success.

2. <u>Despite indications that early and substantial funding may reduce the scope of future cost growth, there is little clearcut effect of "front-end" money on the technical and operational outcomes of the program.</u>

Although no judgements were made of the manner in which development funds were spent, there are indications that the management of the development/system definition phase of the life-cycle should be redirected. The staff report on the acquisition process to the Blue Ribbon Defense Panel in 1970 reported that the services had failed to receive sufficient funding to carry out necessary technical work during the early periods of their programs. What would often happen then was that critical engineering studies would be conducted during the production phase when money was more abundant. It is plausible that an adverse effect on system capabilities and performance would be suffered.

Related to this last point is the complete lack of effect that development investment displayed when defined as a ratio of development funding to program cost. It may be entirely possible that the definition of development investment is inadequate to the task of measuring technical uncertainty. Despite the fact that a majority of programs (40 out of 48) met or surpassed the initial performance goals established for them, and that the "science" of predicting what is technically feasible may be more efficient than the "art" of estimating cost or schedule outcomes, one should be reluctant to surmise that developmental effort has less

effect on project success than other program variables. Although certainly less program resources are committed to advancing the state-of-the-art than manufacturing final hardware, judging from figures for the cost growth of strictly development budgets as reported by Peck and Scherer, cost variance has exceeded three or four times the original estimates in the past. It is conceivable that these developmental excesses could have a snowballing effect of the remainder of the program, expecially on schedule milestones if stirct measures against concurrent development and production are taken.

3. Program length is related inversely to the achievement goals.

It appears from an examination of all the characteristics that performance estimates were either met or exceeded, and so it is surprising to find indications that program length is related in a positive way to achievement of desired performance. Peck and Scherer came across a possible explanation in their study.

> Each engineer wants to perfect things on which he works. Every development nevertheless involves compromises between quality and time. If schedules are set too generously, there is a tendency for persons working on the progect to use up the scheduled time and still be no nearer completion on their hardware goals than under a shorter schedule. Therefore, in order to provide a good target a schedule should be short enough to make people think

and worry about getting the hardware out.[18]

Unfortunately, program length contributed very little else to an understanding of program success.

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[18] Peck, M. J. and Scherer, F. M., The Weapons Acquisition Process: An Economic Process, p. 413, Research Division, Graduate School of Business Administration, Harvard University, 1962

IV. COMMENTS AND RECOMMENDATIONS

Fundamental to this thesis was the point of view from which the analysis was conducted. Each of the forty-eight programs were considered as "black boxes" into which certain inputs were made (cost, time, effort, etc.) and from which certain measurable outputs were collected. Meadows and Marquis criticized such "post mortem" techniques in their own analysis of the implications of forecasting errors for ignoring the interaction between forecasts and outcomes in the process of development.[19] Additionally, Determinants of Project Success by Murphy, et al, stated, "with rare exception, the determinants of project success were management factors, things which management had the potential ability to influence...",[20] a conclusion which necessarily required a point of view from within the box.

The analysis undertaken here does not mean to suggest that management techniques are without effect in determining program outcomes. Instead, the study asked how program initial conditions related to program outcomes, or more precisely, to what extent could the initial conditions be

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[19] Meadows, D. L. and Marquis, D. G., Characteristics and Implications of Forecasting Errors in the Selection of R&D Projects, paper delivered by D. L. Meadows at The Second Annual Technology and Management Conference, Washington, D.C., 21 March 1968

[20] Murphy, D. C., Baker, B. N., and Fisher, D., Determinants of Project Success, p. 5, Management Institute, School of Management, Boston College, 1974

relied upon to "explain" program success. 'Explain' is used here in the sense of signalling the degree of success that a program most likely would enjoy. And because of that, Meadows and Marquis are correct, the transfer function of the black box is not really of primary concern. Actually, the results of this study do uphold Murphy in that the weakness of the correlation implies that other determinants are at work.

Before dismissing the methodology as indecisive at best, perhaps a few suggestions as to how to improve it would be in order. During the accumulation of data for the thesis, a concerted effort was made to ascertain a measure of the relative importance of each project without success. The Navy practice of assigning importance classification based on the significance of the preceived threat to program once the Specific Operational Requirement has been drafted is no longer in effect, and no joint ranking system appears to exist. The addition of this extra variable as a measure of how the program is perceived outside the project office would strengthen greatly the correlation prodedure and no doubt serve as the basis for an interesting hypothesis as well.

It is felt that the data from the SAR should be supplemented by information gained from other sources, such as interviews or questionaires. For instance, the dilemma as to what effect technological advance has on project success

could be settled by correlating the technical assessment of program office engineering personnel with the SAR measurement. Additionally, some understanding of how initial forecasts drive the program, that is how the attitude of managers toward these development estimates is reflected in the outcome, might prove an interesting variable in itself. Obviously though, the distance between the analyst and the programs would have to be shortened.

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APPENDIX A

SELECTED ACQUISITION REPORT

31 MARCH 1976

A-7E

UNCLAS

05 MAY 1976

Navy Department Security Review of the attached document has been completed. ~~The information bracketed for deletion is classified~~. There is no security objection to public release~~/publication of the unclassified portions of the remaining material~~.

OP-009B3 Navy Security Review F. A. IRWIN
By direction

UNCLASSIFIED

SELECTED ACQUISITION REPORT

A. 1. Dates:

A. As of Date: 31 March 1976
B. Submission Date: 15 April 1976

2. Designation: A-7E

3. Nomenclature: Airplane; Attack, Visual (Light) (U)

4. Popular Name: CORSAIR II

5. Mission and Description: The A-7 aircraft is a land/carrier-based subsonic, medium range, visual light attack aircraft carrying tactical nuclear weapons and practically all types of conventional ordnance in the Navy's inventory while performing close tactical air support or interdiction missions. The A-7E incorporates the AVQ-7 Head Up Display, the ASN-91 Tactical Computer, the ASN-90 Inertial Measurement Set and an integral M-61 20MM, Gatling type machine gun. In early CY 1978 to provide the pilot the ability to see targets during darkness a forward looking infra-red imaging system (TRAM) will be incorporated. The A-7E replaces the A-4 and earlier models A-7A and A-7B.

6. Prime/Associated Prime Contractor Name and Major System/Subsystems: Vought Systems Division, LTV Aerospace Corp., Dallas, Texas - A-7E Aircraft. Detroit Diesel, Allison Division, General Motors Corp., Indianapolis, Indiana - TF41-A-2 Engine.

7. DOD Component: Department of the Navy

8. Responsible Office and Phone Number: CAPT Frederick S. Dunning, Jr., USN, PMA-235, 202-692-3359.

9. Reference Documents and Dates:
a. The parameters are extracted from the basic specification SD-555-5 of 21 March 1968 (Section C).
b. The contract performance guarantees in Column 2 are reflected in the detail specifications SD-555-5 of 21 March 1968 as amended 25 March 1970 (Section C).
c. TDP W11-25 of 5 June 1968 (Section D).
d. TDP W11-26 of 1 April 1969 (Section D).
e. For the first 7 FY 67 aircraft, actual costs were used ($79.3M) and 31 May 1968 FYDP costs

(Dollars in Millions)

were used for the remainder. Since FYDP costs appear only as gross program "single line" entries, it was necessary to allocate the FYDP total among airframe, GFE and support costs. This was done by apportioning the total 588 aircraft FYDP dollars ($1,367.0) among airframe, GFE and support costs in exactly the same ratios as the price outs for costs appearing in col 3 (Section E).

B. Program Highlights

1. a. The current estimate of total program costs increased $57.3M since the last report. This is the net result of prior year reductions and repricing of the outyear program at current known prices.

b. The Navy plans to have a force level of 24 operational attack A-7E squadrons by the end of FY 1979. There are currently 20 A-7E squadrons. There are now 10 A-7E squadrons on the East Coast and 10 A-7E squadrons on the West Coast.

c. Total program cost is $3137.1M of which $1880.5 are sunk costs (oblig as of 31 March 1976) and $1256.6M is the program cost to complete.

d. The A-7E initially deployed successfully in April 1970 on schedule. It has flown 40,020 combat sorties for a total of 80,817 combat hours. The A-7E met or bettered all contract guarantees and the contractor is currently delivering aircraft on schedule. All subsystems are meeting mission requirements.

e. The A-7E was temporarily suspended from flight operations from 31 August 1975 to 3 September 1975 primarily due to hot section distress on first stage turbine inlet guide vanes in TF41 engine. Concurrent with the hot section distress were two separate problems with the first stage low pressure fan blade and the second stage turbine blade. The first stage fan blade problem was solved by inspections. Components in the turbine section have been assigned life limits and temporary restrictions on the use of full-rated power are in effect pending technical resolutions. A Joint USAF/Navy component improvement program designed specifically to restore reliability and durability to the TF41 engine is ongoing.

B. Program Highlights (Cont'd)

f. The government of Greece has ordered 60 modified A-7E/D's designated as the A-7H. A total of 18 have been delivered.

2. Change Since "As of Date": A current review of prices for this program indicates a possible price increase of about $60M. Upon verification, this will be reflected in the 30 June 1976 SAR.

3. Development Concept Paper Thresholds Breached: Not applicable.

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were used for the remainder. Since FYDP costs appear only as gross program "single line" entries, it was necessary to allocate the FYDP total among airframe, GFE and support costs. This was done by apportioning the total 588 aircraft FYDP dollars ($1,367.0) among airframe, GFE and support costs in exactly the same ratios as the price outs for costs appearing in col 3 (Section E).

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As of Date: 31 March 1976

Program: A-7E

B. OPERATIONAL/TECHNICAL CHARACTERISTICS	1 DEVELOPMENT ESTIMATE (A)	2 APPROVED PROGRAM (B)	3 DEMONSTRATED PERFORMANCE	4 CURRENT ESTIMATE
Operational				
1. Speed				
a. Max Speed at Sea Level Military Power (KT) (1)	505	543*	555	Successfully demonstrated and removed to demonstrated column
2. Radius/Range				
a. Primary Attack Mission with 3600 lb bombs aboard (NAUT. MI) (1)	537	418*(2)	475	
3. Ceiling/Altitude				
a. Combat Ceiling (FT)	35,000	35,500	35,500	
4. Reliability % (1)	78.2	78.2*	84.0	
5. Maintainability				
a. SDLM**	24 (Mo)	24 (Mo)	30 (Mo)	
b. Direct Maintenance Man Hours per flight hour (1)	9.6	9.6*	5.4	
Technical				
6. Weight (lbs)				
a. Empty	17,569	18,219	18,165	
b. Normal Take-off (1)	33,273	34,213*	34,159	
c. Maximum Take-off	38,000	42,000	42,000	

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*Contract Guarantee
**Scheduled Depot Level Maintenance

C. OPERATIONAL/TECHNICAL CHARACTERISTICS (Cont'd)	1 DEVELOPMENT ESTIMATE (A)	2 APPROVED PROGRAM (B)	3 DEMONSTRATED PERFORMANCE	4 CURRENT ESTIMATE
Technical				
7. Dimensions				
a. Length, Overall (Ft)	46.13	46.13	46.13	
b. Wingspan, Spread (Ft)	38.73	38.73	38.73	
c. Wingspan, Folded (Ft)	23.77	23.77	23.77	
d. Height (Ft)	16.06	16.06	16.06	
e. Wing Area (Sq Ft)	375.0	375.0	375.0	
8. Engine Model	TF-30-P-408	TF-41-A-2	TF-41-A-2	
Uninstalled Sea Level Thrust	12,200 (3)	15,000	15,000	

Comments:

Characteristics shown are selected parameters which essentially describe the military worth of the aircraft.

(1) Formal contract guarantees are based on attack mission "B" which includes 12 MK-81 SNAKEYE I bombs (3600 lb).

(2) The Naval Air Systems Command has effected an administratively simple re-designation of the first 67 A-7E aircraft, which were powered by the Pratt-Whitney TF30-P-8 (now powered by an uprated TF30-P-408, 13400 lbs thrust) to a model "A-7C" designation. The sixty-eighth and subsequent aircraft are powered by the superior Allison TF41-A-2 engine, and will continue to be designated as "A-7E's". Different model designations for the different engines improve the utility of operational and material reports and will thereby ensure improved logistic support of both aircraft.

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Variance Analysis:

Column 4 vs 1

C-1 A new more powerful engine, the TF-41-A-2, increased max speed.

C-2 The TF-41-A-2 engine used more fuel which decreased radius and range.

C-3 The TF-41-A-2 engine increased combat ceiling.

C-4 Reliability was demonstrated and witnessed by Navy Representatives.

C-5a Standard depot level maintenance interval was increased because experience indicated that overhaul was not necessary at shorter intervals.

C-5b Direct maintenance man hours per flight hour was determined by actual Navy experience.

C-6 & 8 A new more powerful engine, the TF-41-A-2 engine increased speed, maneuverability, load carrying capability, weights and decreased take off distance.

Changes Since Previous Report:

None

Program: A-7E

As of Date: 31 March 1970

D. Schedule Milestones	1 Development Estimate	2 Approved Program	3 Current Estimate
1. Project Initiated	May 63	N/A	N/A
2. Contract Award (Prod) A-7E c/	Dec 67	Dec 67	Dec 67*
3. First Flight c/	Nov 68	Nov 68	Nov 68*
4. Accept First Prod Aircraft c/	Nov 68	Nov 68	Nov 68*
5. Start Military Preliminary Eval c/	Dec 68	Dec 68	Feb 69*
6. Begin Board of Inspection Survey Trials c/	Jan 69	Jan 69	Sep 69*
7. Fleet Introduction c/	Feb 69	Feb 69	Jul 69*
8. Navy Support Date c/	Feb 69	Feb 69	Jul 69*
9. Fleet Operations d/	Apr 70	Apr 70	Apr 70*

Unit Accepted to Date
Plan/Actual 485/485

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4

Variance Analysis:

Column 3 vs 1

D 5 - The start of the MPE was delayed two months due to design, flight testing and production slippages of the avionics equipments.

D 6, 7, and 8 - There is a chain reaction between MPE, fleet introduction and commencement of formal BIS trials. Bad weather at Dallas, which delayed test flying, plus the unforeseen flight hours, delayed completion of the MPE 3 months. Inasmuch as "fleet introduction" naturally dictates the "fleet support" date, and because these depend on the mutually related MPE/BIS dates the actual date of initial fleet support slipped from Feb 69 to July 69.

Changes Since Previous Report:

None

(Dollars in Millions)

1. Program Acquisition Cost	(1) Development Estimate e/ (FY67-FY72)	(2) Changes	(3) Current Estimate (FY67-FY81)
Development			
In-House	6.0	0	6.0
Contractor	13.3	15.5	28.8
Sub-Total	19.3	15.5	34.8
Procurement			
Flyaway			
Airframe and Changes	771.6	319.7	1091.3
Engine and Accessories	205.9	106.1	312.0
Electronics and Comm	48.1	84.3	132.4
Armament & Other GFE	42.1	10.7	52.8
Total Flyaway	1067.7	520.3	1588.5
Support			
Ground Support Equip	162.4	125.9	288.3
Trning and Other Support	68.9	54.3	123.7
Initial Spares	147.3	65.1	212.4
Sub-Total Procurement	1446.3	766.6	2212.9
Construction	0	1.3	1.3
Total: Constant FY 67 $	1465.6	783.4	2249.0
Escalation	0	888.1	888.1
Total Program Cost	1465.6	1671.5	3137.1
2. Quantities			
Development	0	0	0
Procurement	595	97	692
Total	595	97	692
3. Unit Costs			
Procurement			
Constant FY 67 $	2.431	.767	3.198
Escalated	2.431	2.036	4.466
Program			
Constant FY 67 $	2.463	.787	3.250
Escalated	2.463	2.070	4.533

4. Approved Design to Cost Goal: N/A

Funding	(4) Current and Prior Years	(5) Budget Year (FY 77)	(6) Balance to Complete* FYDP	(7) Beyond	(8) Total
Development	44.[illegible] (CH-E1)	.2	-0-		44.[illegible] (CH-E1)
Procurement	19[illegible].[illegible] (CH-E2)	235.2	562.6 (CH-E2)		30[illegible].5 (CH-E2)
Construction	1.5	-	- 0 -		1.5
Total	2019.1 (CH-E1/2)	235.4	582.6 (CH-E1/2)		3137.1 (CH-E1/2)

Quantities

Development	0	0	0		0
Procurement	542	30	120		692
Total	542	30	120		692

*The $18.4M advance funding FY 81 reflected in the data sheet is for planning purposes for follow-on aircraft and is not included in the cost of this program.

ESTIMATES

Column (1) reflects the set of circumstances existing as of mid 1967 that was arbitrarily selected in order to satisfy SAR requirements and does not include any escalation factors. The current estimate, column (3) includes adjustments for program changes and economic escalation greater than initially assumed. For that part of the program subject to future escalation a weighted average escalation rate of 5.8% annually through FY 86 is assumed. The table below indicates that change to the current estimate of $3137.1M which would result from other rate assumptions.

ESCALATION RATE	$ MILLIONS
2%	-76.3
4%	-38.6
8%	+42.2
10%	+84.3

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A-7E
COST VARIANCE ANALYSIS
(Dollars in Millions)

BASE YEAR/FY 67 CONSTANT $

	DEV	PROC	CONST	SUB-TOTAL	ESCALATION	TOTAL	REMARKS
Development Estimate	$19.3	$1446.3	0	$1465.6	0	$1465.6	
Previous Changes							
Economic					+401.1	+401.1	Dev $.2M; Proc $400.9M
Quantity		+325.9		+325.9	+205.9	+531.8	Esc: $205.9M (Incl $101,1M from year of change approval)
Engineering	+15.4	+151.4		+166.8	+ 84.3	+251.1	Esc: $9.8M Dev, $74.5M Proc (Incl $9.8M Dev and $14.8M Proc from year of change approval)
Schedule		+188.5		+188.5	+ 91.7	+280.2	Esc: $91.7M (Incl $66.7M from year of change approval)
Support		- 24.5	+1.3	- 23.2	+ 13.4	- 9.8	Esc: $.2M MILCON, $13.2M Proc (Incl $5.9M from year of change approval)
Estimating		+ 98.5		+ 98.5	+ 61.3	+159.8	Esc: $61.3M (Incl $30.0M from year of change approval)
Sub-Total	+15.4	+739.8	+1.3	+756.5	+857.7	+1614.2	
Current Changes							
Estimating	+ .1	+ 24.8		+ 24.9	+ 27.4	+ 52.3	Esc: $27.4M(Incl $8.1M fm yr of change approval)
Support		+ 2.0		+ 2.0	+ 3.0	+ 5.0	Esc: $3.0M (Incl $1.0M fm yr of change approval)

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A-7E
COST VARIANCE ANALYSIS
(Dollars in Millions)

BASE YEAR/FY 67 CONSTANT $

	DEV	PROC	CONST	SUB-TOTAL	ESCALATION	TOTAL	REMARKS
Current Changes (Cont'd)							
Sub-Total	+ .1	+ 26.8		+ 26.9	+ 30.4	+ 57.3	
TOTAL CHANGES	+15.5	+766.6	+1.3	+783.4	+888.1	+1671.5	($9.8M Dev, $227.6M proc from year of change approval)
CURRENT ESTIMATE	34.8	2212.9	1.3	2249.0	888.1 (10.0 Dev) (877.9 Proc) (.2 Const)	3137.1	($9.8M Dev, $227.6M proc from year of change approval)

PREVIOUS CHANGES

(1) Economic (Total $401.1M)

(2) Quantity (Total $531.8M)

Increase in Quantity from 595 to 692 and finalization of prior year contract mods ($1.1M)

(3) Engineering (Total $251.1)

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As of Date: 31 March 1976
Base Year: 1967

A-7E
COST VARIANCE ANALYSIS
(Dollars in Millions)

PREVIOUS CHANGES (Cont'd)

Engineering Changes associated with changing engine to TF41, TRAM incorporation, changes associated with A7B to A7E configuration and other small changes. Addition of larger capacity, computer in FY TQ through 80 ($6.4M). Production incorporation of Inflight Engine Condition Monitoring System FY 76 through FY 80 ($19.5). Reduction in dev funds ($2.4M). Addition of High Speed Anti-Radiation Missile (HARM) FY 78 through FY 81).

(4) Schedule (Total $280.2M)

USN/USAF stretch out over a 13 year period in lieu of originally planned 5 year period.

(5) Support (Total -$9.8M)

Decrease due to transfer of $50.0M spares funding. Increase of spares costs ($28.9M) due to final pricing of prior years spares contracts and realignment of spares costs FY 76 through FY 80, adding FY 81 support and addition of HARM. Addition of TRAM support ($19.5M) due to realignment of support requirements. Reduction ($9.7M) due to final pricing of prior years support. $1.5M MILCON added.

(6) Estimating (Total $159.8M)

Due to repricing of engine costs, advance procurement realignment, final pricing of prior year contracts, and breakout of high cost Electronics from CFE to GFE. (+$26.2M) Repricing of total program FY 76 through FY 80 at current known prices ($+77.3M). Final pricing of prior year contract mods (+$0.3M). Increases to support equipment costs in FY 77 to FY 80 ($56.0M). The sale of the A-7H to Greece saved the Navy $4.4M in FY 76. This saving is reflected in the current appropriation.

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As of Date: 31 March 1976
Base Year: 1967

A-7E
COST VARIANCE ANALYSIS
(Dollars in Millions)

CURRENT CHANGES

(1) Estimating (Total $52.2M)

Net result of -$.2M in prior years reprogramming actions due to final pricing of prior year contract modifications and increase of $52.4M in fiscal years 79 through 81 due to repricing of the out year program at current known prices.

(2) Support (Total $5.0M)

Net result of +$.4M support and -$2.6 spares in prior years reprogramming actions due to final pricing of prior year contract modifications and increase of $7.2M in fiscal years 79 through 81 due to repricing of out year support at current known prices.

CHANGES SINCE LAST REPORT

CH-E1 Increase of +.1 due to final pricing of prior year development costs. (reprogramming)

CH-E2 Net result of -2.4 in prior years reprogramming actions due to final pricing of prior year contract modifications and increase of 59.6M in fiscal years 79 through 81 due to repricing of the out year program at current known prices.

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(Dollars in Millions)

F. Contract Costs (1)	1 Initial Contract Price	2 Current Contract Price Target	3 Ceiling (2)	4 Price @ Completion Contractor Estimate	5 Price @ Completion Government Estimate
Procurement Vought Systems Div FPI					
N00019-70-C-0497 Ltr 10/31/70 Def 3/31/71	37.2	51.7	62.0	51.7	51.7
N00019-71-C-0497 6/25/71	50.7	56.3	67.6	56.3	56.3
N00019-72-C-0098 5/13/72	43.7	59.2 (CHF1)	71.0 (CHF1)	59.2 (CHF5)	59.2 (CHF5)
N00019-73-C-0302 8/23/73	92.4	106.9 (CHF2)	128.3 (CHF2)	107.8 (CHF5)	107.8 (CHF5)
N00019-74-C-0126 8/15/74	55.0	60.3 (CHF3)	72.4 (CHF3)	61.1 (CHF5)	61.1 (CHF5)
N00019-75-C-0164 8/29/75	58.1	60.2 (CHF4)	72.2 (CHF4)	61.6 (CHF5)	61.6 (CHF5)

1. All Navy TF-41-A-2 engines are procured by MIPR to the U. S. Air Force who is currently administering the entire TF-41 procurement. The engine is procured from Detroit Diesel, Allison Division, General Motors Corporation, Indianapolis, Ind.
2. Computed at 120% of target.

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Program: A-7E

Changes Since Previous Report:

CH-F1 Target price increased $.2M since the last report due to incorporation of negotiated and formalized modifications and a net change of +$.2M in ceiling price.

CH-F2 Target price increased $.1M since the last report due to incorporation of negotiated and formalized modifications and a net change of +$.1M in ceiling price.

CH-F3 Target price increased $.3M since the last report due to incorporation of negotiated and formalized modifications and a net change of +$.4M in ceiling price.

CH-F4 Target price increased $2.1M since the last report due to incorporation of negotiated and formalized modifications and a net change of +$2.5M in ceiling price.

CH-F5 This reflects the total funds including limitation items currently on contract and may be increased or decreased as necessary during the life of the contract. The adjustments since the last report varies from +$0.2M to +$2.8M.

Program: A-7E

BUDGET YEAR AND OUT YEAR PROGRAMS As of Date: 31 March 1976

Fiscal Year	Current Estimate Budget Year & To Complete Dev.	Proc.	Const.	Dev.	Escalation (Base-Year-FY 67) Amount Proc.	Const.	Dev.	Rate a/ Proc.	Const.
FY 1977	.2	235.2		.1	101.6		7.6	7.6	
FY 1978		251.6			122.1			8.0	
FY 1979		218.9			111.8 CH-1			4.0	
FY 1980		218.3			115.3 CH-2			4.0	
FY 1981		193.8			105.9 CH-3			4.0	
TOTAL	.2	1117.8		.1	556.7				

a/ Since the annual rates shown do not incorporate spend-out rates nor the compounding effect of prior year's escalation, they cannot be used to track the inflation amounts shown for applicable years.

CH-1 +15.3
CH-2 +11.6
CH-3 + 4.2

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APPENDIX B

COMPUTATION OF IMPLICIT PRICE DEFLATORS

The Direct Budget Plan (TOA) History (following page) was the source of the implicit price deflators discussed earlier. The following example will demonstrate how these conversion factors were derived.

A - 7E Program

From the SAR in Appendix A, the program base year is established as 1967. Then, from the TOA history, the ratio of FY 1967 obligations to an equivalent amount of 1977 dollars is computed. This is:

$$\$21,190M/\$42,904M = 0.493$$

Similarily, a ratio of FY 1974 obligations to 1977 dollars is also calculated. This is:

$$\$26,888M/\$32,926M = 0.817$$

The second ratio is then divided by the first and the result is a price deflator for converting 1967 dollar amounts to an equivalency in 1974 dollars.

$$0.817/0.493 = 1.66$$

Department of the Navy

DIRECT BUDGET PLAN (TOA) HISTORY

($ Millions)

Fiscal Years 1964 - 1977

	[illegible]	FY 66	FY 67	FY 68	FY 69	FY 70	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY TQ	FY 77
MPN	2,977	3,587	3,924	4,158	4,455	4,854	4,711	5,091	5,461	5,561	5,812	5,923	[illegible]	[illegible]
MPMC	725	978	1,250	1,431	1,535	1,627	1,462	1,456	1,578	1,661	1,746	1,870	[illegible]	[illegible]
RPN	95	109	113	121	121	142	156	199	232	220	211	207	[illegible]	[illegible]
RPMC	29	36	37	36	36	49	54	58	68	60	65	72	[illegible]	76
O&M,N	2,890	3,936	4,616	4,968	5,360	5,223	4,946	5,274	5,410	6,557	7,274	8,300	[illegible]	[illegible]
O&M,MC	190	333	429	434	459	407	403	362	383	442	459	520	131	580
O&M,NR	-	-	-	-	-	-	-	-	138	195	245	286	[illegible]	[illegible]
O&M,MCR	-	-	-	-	-	-	-	-	8	12	12	12	3	[illegible]
NPR	-	-	-	-	-	-	-	-	-	-	68	119	-	-
PAMN	2,487	3,452	3,633	3,248	3,124	2,794	3,309	3,932	3,647	-	-	-	-	-
APN	-	-	-	-	-	-	-	-	-	2,939	2,777	2,964	606	[illegible]
WPN	-	-	-	-	-	-	-	-	-	799	739	1,178	[illegible]	[illegible]
SCN	2,005	1,861	2,258	1,146	1,005	2,401	2,242	3,013	2,908	3,513	3,111	3,928	471	[illegible]
OPN	1,106	1,947	2,228	2,153	2,376	1,896	1,657	1,729	2,249	1,376	1,570	1,840	465	[illegible]
PMC	195	725	486	679	590	465	226	120	175	208	216	281	40	[illegible]
RDT&E,N	1,548	1,565	1,921	1,878	2,178	2,267	2,199	2,411	2,542	2,704	3,052	3,317	826	3,925
MCON	195	646	289	525	307	311	316	381	506	619	556	774	17	595
MCNR	7	10	5	5	5	9	5	11	21	23	22	36	*	17
NSF												10		32
MCSF												2		9
Total (Current)	14,450	19,185	21,190	20,781	21,582	22,444	21,685	24,036	25,326	26,888	27,934	31,640	7,251	37,386
★Total (Constant)	32,480	40,467	42,904	40,717	40,006	38,263	34,475	[illegible]	34,130	32,926	31,294	33,341	7,326	37,386

★Base Year = FY 1977

* Less than 500 thousand

Note: Totals may not add due to rounding

APPENDIX C

COMPUTATION OF OUTCOME VARIABLES

Listed in the following pages are the forty-eight programs which constituted the sample of acquisition programs studied and their associated outcomes. Before proceeding further, it was felt that some examples of how each of the outcome factors was obtained would be beneficial. The A-7E SAR in Appendix A will serve as a data source.

1. Cost Growth (%)

As stated previously in Chapter II, the measure of relative cost growth was obtained directly from "SAR Program Acquisition Cost Summary". That document reported the A-7E project relative cost growth as + 26%. Thus, the program has a cost growth factor of 1.26.

2. Performance

In Chapter II, the achieved performance factor is stated as being derived as a weighted average of key performance criteria. In the case of the A-7E program, these were:

1. maximum speed at sea level;
2. radius/range during primary attack mission;
3. ceiling/altitude;
4. reliability;
5. maintainability -
    a. Scheduled Depot Level Maintenance (SDLM)
    b. Maintenance Man-Hour per Flight Hour.

A comparison of the current estimate/demonstrated performance and the development estimate for each of the criteria above yields the following results.

1. 505 KTS/555 KTS = 0.91

2. 537 NM/475 NM = 1.13

3. 35,500 ft/35,000 ft = 1.00

4. 0.78/0.84 - 0.93

5a. 24 MOS/30 MOS = 0.80

b. 5.4 HR/9.6 HR = 0.56

(Weighted equally, maintainability is 0.68)

Summing all of the scores and dividing by the number of criteria, one achieves a performance factor of 0.93 for the program.

The above procedure is illustrative of the general approach used. There were two modifications to this method, one in the case of ships, the other in the case of certain one-shot devices. Unlike aircraft where speed, maneuverability, range, reliability and maintainability taken together represent a meaningful measure of system performance, a comparison of SAR criteria for ships (e.g., speed, manning level, displacement, etc.) does not. Invariably these criteria are met. The existence of multiple mission areas for a single ship type further complicates the figure of merit calculations. This is a good example of where system evvectiveness breaks down in a computational sense. For these

reasons, ship systems were arbitrarily assigned a performance factor of 1.0.

One-shot systems (less strategic systems) were evaluated based on a comparison of their single shot probability of kill given in the SAR. This assumed the systems were activated within their proper search/attack envelopes and that all components functioned properly.

3. Schedule Growth (%)

From the Schedule Milestone section of the SAR, the program was initiated in May 1963 and achieved an IOC on schedule in April 1970. Thus, there was no schedule slippage and a factor of 1.0 was awarded.

PROGRAM OUTCOME SUMMARY BY SERVICE

NAVY

	Program	Performance	Cost Growth(%)	Schedule Slip(%)
1.	S-3A	1.04	1.03	1.00
2.	Trident	1.00	0.99	1.14
3.	Poseidon C-3	1.00	N/A	1.07
4.	SSN 688	1.00	1.01	1.15
5.	Trident C-4	1.00	1.06	1.13
6.	DD 963	1.00	1.05	1.24
7.	CGN 38	1.00	1.05	1.24
8.	Harpoon	1.00	1.10	1.13
9.	LHA	1.00	1.18	1.87
10.	CVAN 68	1.00	1.16	1.35
11.	CVAN 69	1.00	1.25	1.24
12.	Condor	0.94	1.46	3.29
13.	CH-53E	0.97	1.08	1.32
14.	MK 48-1	0.98	1.19	1.14
15.	P-3C	0.99	1.17	1.05
16.	Captor	1.00	1.56	1.33
17.	Sparrow III	1.00	1.64	2.80
18.	PHM	1.00	1.84	1.41
19.	Phoenix	1.00	1.43	1.06
20.	FFG 7	1.00	1.45	1.13
21.	A-7E	0.93	1.26	1.00
22.	E-2C	0.89	1.36	1.03

Program	Performance	Cost Growth(%)	Schedule Slip(%)
23. Phalanx	0.85	1.37	1.36
24. F-15A	0.84	1.22	1.16
25. Sidesinder (AIM 9-L)	0.79	1.61	2.45
MEAN	0.969	1.272	1.404

ARMY

Program	Performance	Cost Growth(%)	Schedule Slip(%)
1. XM 198	1.16	1.03	1.30
2. Stinger	1.62	1.22	1.44
3. Hawk	1.04	1.39	1.25
4. UTTAS	1.00	0.88	1.02
5. Roland	1.00	1.00	1.23
6. XM 1	1.00	1.08	1.00
7. Patriot	1.00	1.07	1.21
8. AAH	1.00	1.15	1.33
9. MICV	1.00	1.19	1.34
10. Dragon	1.00	1.19	1.50
11. Copperhead	0.93	1.18	1.11
12. TOW	0.86	1.21	1.41
13. Lance	0.86	1.12	1.65
14. TACFIRE	0.88	1.38	N/A
MEAN	1.025	1.149	1.292

USAF

Program	Performance	Cost Growth(%)	Schedule Slip(%)
1. F-16	1.06	1.00	1.00
2. B-1	1.12	1.13	1.35
3. A-10	1.03	1.22	1.13
4. E-3A	1.02	1.16	1.10
5. EF-11A	1.00	0.94	1.00
6. Maverick	1.00	1.02	1.22
7. E-4	1.00	1.40	1.61
8. F-14	1.00	1.25	1.03
9. Minuteman III	0.82	1.15	1.00
MEAN	1.006	1.141	1.160
OVERALL MEAN	0.992	1.210	1.326

"SAR PROGRAM ACQUISITION COST SUMMARY"

Weapon System	Status	Program Base Year	DEVELOPMENT ESTIMATE – Program Cost: Program Base Year Dollars	Projected Escalation	Total	COST CHANGES TO DATE: Quantity Changes in Program Base Year Dollars	Other Changes in Program Base Year Dollars	Actual and Projected Escalation	Total	CURRENT ESTIMATE – Program Cost: Program Base Year Dollars	Actual and Projected Escalation	Total	COST CHANGES THIS QUARTER: Program Changes in Base Year Dollars	Actual and Projected Escalation	Total	% COST GROWTH: Base Year Adjust for Quantity	Total Adjust for Quantity
CONGRESSIONAL SAR SUBMISSION																	
ARMY																	
LANCE (Battalions)	Proc	1979	638.0	14.9	632.9	144.5	94.2	111.8	351.5	976.7	127.7	1004.4	-	-	-	12	14
IMP-HAWK (Battery Sets)	Proc	1969	588.2	-	588.2	-8.2	213.4	245.3	460.5	803.4	245.3	1048.7	-2.1	-1.0	-3.1	39	59
PATRIOT (Fire Sections)	Dev	1972	4239.6	1000.9	3240.5	-1031.2	215.2	1329.3	713.3	3423.6	2330.2	5933.8	-	-	-	7	43
HELLFIRE	Dev	1975	508.2	216.9	735.1	-	-	-	-	508.2	226.9	735.1	-	-	-	-	-
UTTAS	Dev	1971	1941.7	363.6	2307.3	-20.2	-215.5	1303.2	1057.5	1696.0	1668.8	3364.8	-1.3	-0.6	-1.9	-12	47
AAH	Dev	1972	1452.8	347.4	1800.2	119.4	138.7	1380.6	1658.7	1730.9	1728.0	3438.9	137.0	194.3	331.3	10	66
MICV	Dev	1972	207.4	38.0	245.4	146.0	63.5	306.1	517.6	418.9	344.1	763.0	-	-	-	19	41
XM-1	Dev	1972	2328.3	677.1	3005.4 a/	-	1.9	1911.4	1913.3	2330.2	2388.5	4918.7	-0.4	-	-0.4	-	64
ROLAND (Fire Units)	Dev	1975	838.0	281.5	1119.5 a/	-35.2	65.4	37.2	67.4	868.2	318.7	1186.9	19.3	7.8	27.1	8	12
COPPERHEAD	Dev	1975	842.9	397.8	1240.7	-	-1.9	-19.5	-21.4	841.0	378.3	1219.3	-	-	-	0	-2
XM-198	Dev	1972	111.1	10.8	121.9	19.5	23.3	81.8	113.6	153.9	93.6	247.5	0.7	0.2	0.9	18	53
NAVY																	
A-7E	Proc	1967	1463.6	-	1465.6	315.9	474.3	906.3	1706.5	2263.8	906.3	3172.1	16.8	18.2	33.0	26	59
E-2C	Proc	1968	531.4	54.8	386.2	368.3	323.7	620.4	1312.4	1223.4	675.2	1398.6	1.0	0.8	1.8	36	45
F-14A	Proc	1969	3391.4	774.6	6166.0	-30.3	1178.3	1362.1	2510.1	6539.4	2136.7	8676.1	93.5	67.4	162.9	22	34
F-18	~~Dev~~	1975	8003.6	4825.5	12831.1	-	-0.1	-	-0.1	8003.5	4825.5	12831.0	-0.1	-	-0.1	-	-
P-3C	Proc	1968	1294.2	-	1294.2	792.5	347.9	1103.0	2245.4	2434.6	1105.0	3539.6	-1.7	-0.7	-2.4	17	33
S-3A	Proc	1968	2461.1	430.0	2891.1	-59.1	78.2	522.8	541.9	2480.2	932.8	3433.0	62.0	49.1	111.1	3	22
LAMPS MK III	~~Dev~~	1976	1838.3	700.2	2538.5	-	-	-	-	1838.3	700.2	2538.5	-	-	-	-	-
AEGIS	~~Dev~~	1970	394.2	33.4	427.6	-	91.1	69.1	160.1	485.3	102.5	587.8	2.6	2.5	5.1	23	37
CAPTOR	Proc	1971	303.6	23.6	329.2	-6.4	166.4	310.3	470.3	463.6	335.9	799.5	-0.3	-0.2	-0.5	56	148
CONDOR	Proc	1970	434.0	7.0	441.0	-115.0	143.3	119.0	149.3	464.3	126.0	590.3	16.9	11.7	28.6	46	62
HARPOON	Dev	1970	795.0	236.8	1031.8	-36.4	77.5	348.8	389.9	836.1	383.6	1421.7	-1.7	-1.1	-2.9	10	40
PHOENIX	Proc	1963	336.4	-	536.4	13.2	237.2	583.9	836.3	786.8	583.9	1372.7	32.0	36.9	68.9	43	136
SIDEWINDER AIM-9L	Dev	1971	87.2	12.3	99.7	31.1	71.6	89.8	192.3	189.9	102.3	292.2	13.7	6.1	19.8	61	83
SPARROW III F	Proc	1968	453.6	-	453.6	-134.1	191.0	360.6	397.5	490.5	360.6	831.1	21.7	15.5	37.2	64	183
TRIDENT	Dev b/	1974	11194.4	1136.7	11431.1	578.5	734.2	5105.2	6417.9	12607.1	6241.9	18849.0 c/	188.5	170.1	358.6	6	37
MK-48 MOD 1	Proc	1972	1690.0	63.8	1733.8	-335.4	259.0	326.9	230.5	1393.6	390.7	1984.3	-1.0	-0.3	-1.5	19	37
SURTASS	~~Dev~~	1975	203.9	53.4	259.3	-	107.1	126.2	233.3	313.0	179.6	492.6	5.5	2.6	8.1	52	90
SSN-688	Proc	1971	5126.8	620.7	5747.5	1121.5	92.1	2729.7	3943.3	6340.4	3350.4	9690.8	-	-	-	1	26
DD-963	Proc	1970	2394.6	186.6	2381.2	-	116.6	1113.0	1229.6	2511.2	1199.6	3810.8	-	-	-	5	48
CGN-38	Proc	1970	722.3	98.1	820.4	183.2	42.4	203.7	431.3	947.9	393.8	1251.7	-	-	-	5	12
LHA	Proc	1969	1291.3	89.0	1380.3	-436.9	153.4	178.7	-104.8	1007.8	267.7	1275.5	47.5	27.5	75.0	18	35
FFG-7	Proc	1973	2620.4	624.1	3244.5	269.3	1299.3	4201.7	5770.3	4189.0	4825.8	9014.8	338.3	246.4	584.7	45	135
PHM	Dev	73/74	644.6	81.6	726.2	-481.7	136.2	28.1	-318.4	298.1	109.7	407.8	0.1	0.3	0.4	84	111
CVN-68 Class	Proc	68/72/76	3203.3	806.9	4010.2	-	198.3	444.7	643.0	3401.6	1251.6	4653.2	1342.9	631.1	1974.0	6	16
AIR FORCE																	
A-10	Proc	1970	1768.4	721.3	2489.7	-	389.8	1325.3	1715.1	2158.2	2046.6	4204.8	-	-	-	22	69
B-1	Dev	1970	9853.8	1365.0	11218.8	9.5	1239.6	9151.1	10400.2	11102.9	10316.1	21619.0	-	-	-	13	93
F-15	Proc	1970	5988.1	1367.1	7355.2	-	1525.0	3290.9	4815.9	7313.1	4658.0	12171.1	324.1	410.6	734.7	25	65
F-16	Dev	1975	4376.8	1677.7	6034.5	-	-	-	-	4376.8	1677.7	6054.5	-	-	-	-	-
E-3A (AWACS)	Proc	1970	2150.9	510.7	2661.6	-127.7	317.9	707.9	898.1	2341.1	1118.6	3553.7	-	-	-	16	43
E-4 (AABNCP)	Dev	1974	442.9	41.4	484.3	-52.0	157.0	105.8	210.8	547.9	147.2	695.1	-	-	-	40	64
EF-111A	Dev	1973	413.4	218.5	631.9	-	-23.4	-16.2	-39.6	390.0	202.3	592.3	4.0	1.9	5.9	-6	-6
MAVERICK	Proc	1968	331.5	51.9	383.4	31.8	6.0	174.4	212.2	369.3	226.3	595.6	-	-	-	2	36
MINUTEMAN III	Proc	1967	4673.8	-	4673.8	352.6	733.1	2018.7	3104.4	5759.5	2018.7	7778.2	144.5	113.1	257.6	15	46
SIDEWINDER AIM-9L	Dev	1971	115.0	18.7	133.7	33.1	93.8	132.1	259.0	241.9	130.8	392.7	-	-	-	63	102
SPARROW III F	Proc	1968	206.8	47.3	254.1	153.1	82.7	321.5	557.3	442.6	368.8	811.4	-	-	-	23	44
PROGRAM COST SUMMARY																	
ARMY			13696.2	3360.9	17037.1	-665.4	620.2	6889.2	6844.0	13651.0	10130.1	23901.1	153.2	200.7	353.9	5	42
NAVY			33185.2	10861.3	64046.5	2007.2	6321.0	20860.0	29388.2	61713.4	31721.3	93434.7	2180.2	1283.6	3463.8	12	34
AIR FORCE			30321.4	6019.6	36341.0	400.4	4521.5	17211.5	22133.4	35243.3	23131.1	58474.4	472.6	525.6	998.2	15	57
GRAND TOTAL			97202.8	20241.8	117444.6	1742.2	11662.7	44960.7	58365.6	110607.7	65102.5	175810.2	2806.0	2009.9	4815.9	12	42

a/ Planning Estimate; Engineering Development not yet approved.

b/ Applies to missile only; submarine in procurement.

c/ TRIDENT Current Estimate excludes TRIDENT (C-4) Backfit Program Costs estimated at $2,758.9M as of June 30, 1976.

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A statistical analysis of the effectiveness of program initial conditions as predictors of weapon system acquisition program success.